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(54) Title: LIQUID CRYSTAL DISPLAY
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(57) Abstract

A liquid crystal display (10a) capable of operating in both transmissive and reflective modes. The display includes a liquid crystal device (14), and an electro-optic element (27) which comprises a layer of colourless transparent light emitting material sandwiched between a transparent electrode and a reflective electrode. The liquid crystal device (14) is disposed between a front polarizer (12) and a rear polarizer (16). In the transmissive mode, the electro-optic element (27) functions as a backlight, and in the reflective mode it functions as a reflector. The display (10a) also includes a diffuser (28) which increases the viewing angle of the display.

(57) Abrégé

cette invention concerne un affichage à cristaux liquides(10a) capable de fonctionner à la fois en mode de transmission et en mode réfléchissant. L'affichage comporte un dispositif à cristaux liquides (14) et un élément électro-optique (27) comportant une couche de matériau électroluminescent, incolore et transparent, pris entre une électrode transparente et une électrode réfléchissante. Le dispositif (14) est situé entre un polarisateur avant (12) et un polarisateur arrière (16). En mode de transmission, l'élément électro-optique (27) fait office de panneau lumineux, et de réflecteur en mode réfléchissant. L'affichage (10a) comprend également un diffuseur (28) qui accroît l'angle de visionnement de l'affichage.

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(71) Applicant: CENTRAL RESEARCH LABORATORIES LIMITED [GB/GB]; Dawley Road, Hayes, Middlesex UB3 1HH (GB).

(72) Inventor: MOSLEY, Alan; 6 Chiltern Park Avenue, Berkhamsted, Hertfordshire HP4 1EU (GB).

(74) Agent: SHARP, Alan, Cooper; QED I.P. Services Limited, Dawley Road, Hayes, Middlesex UB3 1HH (GB).

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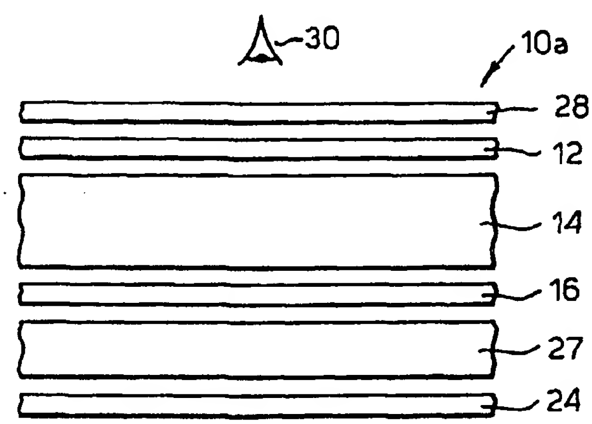

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Description

LIQUID CRYSTAL DISPLAY

Technical Field

The present invention relates to a liquid crystal display.

Background Art

Liquid crystal displays (LCDs) are passive optical devices which are illuminated with a light source in order to produce an image. LCDs may be classified according to the type of light source used to illuminate the display. Where the source of light is ambient light, the display is known as a reflective display. In this type of display, the LCD is placed between a viewer and a reflective surface which is attached to the rear polarizer of the LCD. In this arrangement, the reflective surface reflects light originating from an external source. Reflective LCDs work well in strong ambient light, but are very dim in low ambient lighting conditions.

If a backlight is used in an LCD, then the display is known as a transmissive display. Transmissive displays are useful where the amount of ambient light cannot be guaranteed. However, a disadvantage of these displays is that they have a higher energy consumption than reflective displays. Another disadvantage of transmissive displays is that it is possible for the display image to be severely degraded (or "washed out") in the presence of strong ambient lighting. This is due to reflection of the ambient light at the front surface of the LCD.

Alternatively, if a combination of ambient light and a backlight is used, then the display is known as a transflective display. These displays use ambient lighting when it is available, and a backlight only when necessary. Typically, the transflective material is attached to the rear of a display and, for example, transmits 40% of the light from the backlight, and reflects 60% of the light from ambient lighting. While a transflective LCD works reasonably well in both high and low ambient lighting, its performance is poor compared with purely transmissive or reflective displays.

An aim of the present invention is to provide a liquid crystal display that can operate in both low and high ambient light.

Disclosure of Invention

According to a first aspect of the invention there is provided a liquid crystal display capable of operating in a first mode and a second mode, the display comprising: a liquid crystal device, and an electro-optic element, characterised in that in the first mode the electro-optic element functions as a backlight and in the second mode the electro-optic element functions as a reflector, and the display includes a diffusing means in order to increase the viewing angle of the display.

Preferably the first and second modes are the transmissive mode (where the electro-optic element operates as a backlight to illuminate the display) and the reflective mode (where the electro-optic element acts as a reflector which reflects incident light in order to illuminate the display), respectively.

The liquid crystal device typically consists of a first transparent substrate, a second transparent substrate, and a volume of liquid crystal material disposed therebetween. The liquid crystal material is preferably transmissive in at least one of its states. If the liquid crystal material is of guest-host type (i.e., a dichroic dye dissolved in the liquid crystal), then the liquid crystal device may be used with no polarizer, or with a first polarizing means. Alternatively, for other types of liquid crystal material (such as twisted nematic liquid crystal material), the liquid crystal display preferably includes a further polarizing means. The liquid crystal device is then preferably disposed between the first polarizing means and the further polarizing means.

The electro-optic element comprises a substantially optically transparent first electrode, a second electrode, and a layer of substantially optically transparent light emitting material disposed therebetween. The second electrode is preferably reflective.

Preferably the light emitting material is substantially optically isotropic so that the polarisation of the light passing through the light emitting material is not substantially altered.

Preferably the light emitting layer is colourless so that the colour of the light passing through the light emitting layer is not substantially altered.

The electro-optic element preferably also includes a layer of hole transporting material and/or a layer of electron transporting material. The layer of hole transporting material and/or electron transporting material is preferably substantially optically isotropic so that the polarisation of light passing through the material(s) is not substantially altered. Preferably the layer of hole transporting material and/or electron transporting material is substantially optically transparent and/or colourless, so that the colour of the light passing through the material(s) is not substantially altered.

Preferably the layer of transparent light emitting material is disposed between the layer of hole transporting material and the layer of electron transporting material. Each layer is preferably less than 100 nm thick, and most preferably less than 60 nm thick. The inclusion of a layer of hole transporting material and/or a layer of electron transporting material improves the efficiency of the electro-optic element when it is functioning as a backlight, as more electrical energy may be converted into light than by using only transparent light emitting material.

The reflective second electrode is advantageously adjacent the layer of electron transporting material, and is preferably aluminium, magnesium, or other metal or alloy which has a low work function such as silver, or calcium. If, however, a layer of electron transporting material is not used, the aluminium layer may be situated adjacent the light emitting material layer. The aluminium layer, as well as reflecting light, is also a source of electrons.

The first electrode acts as an anode, and is preferably a layer of Indium Tin Oxide (ITO), or Tin Oxide. This layer may be disposed adjacent the hole transporting material layer (if used), or adjacent the light emitting layer.

The first electrode and/or second electrode may be patterned, or unpatterned.

The optically transparent light emitting material, and the hole and electron transporting materials, are preferably organic materials. The layers of organic material may be patterned, or unpatterned. The light emitting material may be, for example, an organolanthanide. An example of such an organic material is described in published International Patent Application Number WO-A1-9855561 (ISIS Innovation Limited). The hole transporting material preferably includes a substituted aromatic diamine. The electron transporting material preferably includes a derivative of triazole.

The electro-optic element preferably also includes a means of applying a voltage to the first electrode and the second electrode. This voltage may be between 1 and 30 Volts. Preferably, the voltage is between 3 and 15 Volts. A current is generated in the layers of organic material which in turn causes the light emitting material to emit light, thus illuminating the liquid crystal display when the electro-optic device is operating as a backlight.

As the surface of the second electrode of the electro-optic element is typically smooth and mirror-like, it acts as a specular reflector. In order to improve the viewing angle of the display, a diffusing means is provided. The diffusing means scatters light and essentially provides Lambertian (rather than specular) reflectivity, thereby increasing the viewing angle of the display. The diffusing means is preferably composed of a material which does not affect the polarisation of light passing through it. The diffusing means may comprise a diffusing layer. The diffusing layer may include a polymer.

The diffusing layer may be disposed a) adjacent the first polarizing means, b) between the first polarizing means and the liquid crystal device, c) between the liquid crystal device and the further polarizing means, or d) between the further polarizing means and the electro-optic element.

Alternatively, the diffusing means may be formed as part of the electro-optic element. This may be achieved by forming the second (reflective) electrode such that

it diffuses light. In an alternative embodiment, the liquid crystal material may be optically scattering in one of its states, so that a separate diffusing layer is not required.

The liquid crystal display may include a further layer of transparent material, such as, for example, glass. This further layer of transparent material is preferably disposed adjacent the anode of the electro-optic element, and acts as a supporting layer during manufacture of the device.

An encapsulating layer is preferably placed adjacent the cathode of the electro-optic element. This may be glass, plastic, epoxy resin, or other suitable encapsulating material. This layer is preferably less than 0.5 mm thick. The layer may be bonded to the electro-optic element using, for example, an epoxy adhesive.

The electro-optic element may be disposed a) between the further polarizing means and the encapsulating layer, b) between the diffusing layer and the encapsulating layer, c) between the further layer of transparent material and the encapsulating layer.

A transmissive liquid crystal display having a thin light generating film which operates as a backlight (but not as a reflector for the display) is disclosed in US Patent No. 5,796,509 (IBM). However, the light generating film is not optically isotropic, and hence the polarisation of the light passing through the film is changed. This results in the display having low contrast. In addition, the display does not have a means for diffusing light and, as a result, the display does not have a wide viewing angle when viewed in high ambient light.

Brief Description of the Drawings

A number of embodiments of the invention will now be described, by way of example only, with reference to the accompanying Figures, in which:-

Figure 1 shows a cross-section of a liquid crystal display having an organic light emitting backlight (prior art);

Figure 2 shows a cross-sectional view of a liquid crystal device;

Figure 3 shows a cross-sectional view of an organic light emitting backlight; and

Figures 4a, 4b, 4c, 4d and 4e show cross-sectional views of a liquid crystal display having a diffusive layer, according to the invention.

Detailed Description of Preferred Embodiments

A liquid crystal display (10) known in the prior art is shown in Figure 1. The display (10) has a liquid crystal device (14) disposed between a front polarizer (12) and a rear polarizer (16), and a backlight (26) disposed adjacent the rear polarizer. An encapsulating layer (24) is attached to the rear of the display (10), adjacent the backlight. An eye (30) is positioned in front of display (10) in order to illustrate from which side a viewer sees the display.

The liquid crystal device (14) is shown in Figure 2, and typically comprises a volume of liquid crystal material (14b) disposed between front (14a) and rear (14c) layers of transparent substrate.

Referring now to Figure 3, this shows a cross-section of backlight (26) which is formed from a volume of organic light emitting material (20) sandwiched between an anode (18) and a cathode (22). The volume of organic light emitting material (20) is formed from a hole transporting layer (20a), a light emitting layer (20b), and an electron transporting layer (20c).

A number of embodiments of the invention are shown in Figure 4, and these will now be described. Figure 4a shows a liquid crystal display (10a) having a liquid crystal display device (14) disposed between a front polarizer (12) and a rear polarizer (16), and an electro-optic element (27) situated adjacent rear polarizer (16). The electro-optic element (27) has a reflective layer (22). A diffusing layer (28) is situated at the front of the display, adjacent the front polarizer (12).

Figure 4b shows a liquid crystal display (10b) having a liquid crystal display device (14) disposed between a front polarizer (12) and a rear polarizer (16), and an electro-

optic element (27) situated adjacent rear polarizer (16). A diffusing layer (28) is disposed between the front polarizer (12) and the liquid crystal display device (14).

Liquid crystal display (10c) is shown in Figure 4c. Display (10c) has a liquid crystal display device (14) disposed between front polarizer (12) and rear polarizer (16), and electro-optic element (27) situated adjacent the rear polarizer (16). Diffusing layer (28) is disposed between the liquid crystal display device (14) and rear polarizer (16).

Liquid crystal display (10d) is shown in Figure 4d. Display (10d) has liquid crystal display device (14) disposed between front polarizer (12) and rear polarizer (16), and a diffusing layer (28) situated adjacent the rear polarizer (16). Electro-optic element (27) is positioned adjacent the diffusing layer (28).

Figure 4e shows a liquid crystal display (10b) having a liquid crystal display device (14) disposed between a front polarizer (12) and a rear polarizer (16), a glass layer (32) positioned adjacent rear polarizer (16), and an electro-optic element (27) situated adjacent glass layer (32). The positions in which the diffusing layer (28) may be placed are shown in this Figure by dotted lines.

The electro-optic device (27) is susceptible to degradation caused by the ingress of moisture and oxygen from the atmosphere via the reflective layer (22). In order to remove this problem, all of the displays (10a,b,c,d,e) shown in Figure 4 are encapsulated by bonding a thin layer of glass (24) to the rear of the reflective cathode (22).

The structure of the electro-optic element (27) is shown in Figure 3. Each of the layers (20a,b,c) of electro-optic element (27) is approximately 30 to 60 nm thick and optically transparent. Layers (20a,b,c) are also optically isotropic - that is, layers (20a,b,c) will not rotate or significantly alter the polarisation of the polarised light passing through the rear polarizer (16). Anode (18) is composed of a layer of ITO, and may be used to inject holes into layer (20a). Cathode (22) is composed of aluminium (or other suitable low work function metal or alloy) which acts as a good reflector. The cathode provides layer (20c) with electrons.

By including a diffusing layer in the display (10a,b,c,d,e), light reflected by the electro-optic element (27) is made diffuse rather than specular, thereby increasing the viewing angle of the display. Layer (28) may be placed at the front of the display, adjacent front polarizer (12), as shown in Figure 4a. Alternatively, layer (28) may be placed between the front polarizer (12) and the liquid crystal display (14), as in Figure 4b, between liquid crystal device (14) and the rear polarizer (16), as shown in Figure 4c, or between the rear polarizer (16) and electro-optic element (27), as shown in Figure 4d. If placed in the positions shown in Figures 4b, 4c and 4d, the diffusing layer must not affect the polarisation of the light passing through it. This may be achieved by using a polarisation preserving diffuser, such as the holographic diffuser Microsharp I™, manufactured by Microsharp Corporation Limited, UK.

During the manufacture of the display, the electro-optic element (27) is supported by a suitable substrate, such as glass. This is achieved by attaching a layer (32) of substrate to the ITO layer (18) of the electro-optic element (27). Alternatively, the electro-optic element (27) may be supported by the rear polarizer (16), as shown in Figures 4a, 4b, and 4c, or by diffusing layer (28), as shown in Figure 4d.

The use of glass substrate layer (32) is advantageous because glass substrates are usually used in the manufacture of liquid crystal displays. On the other hand, the use of such a layer may be disadvantageous, as the distance between the reflective surface of the electro-optic element (27) and the liquid crystal device (14) is increased by the inclusion of the glass layer (which may be more than 0.3 mm thick). This introduces the problem of parallax which degrades the image.

When the electro-optic element (27) is formed on the rear polarizer (16), the amount of parallax is the same as for conventional reflective or transflective liquid crystal displays. This is because the reflective surface (22) and the LCD (14) are only separated by the organic layer (20), the thickness of which is less than 1 micrometer.

The use of diffusing layer (28) as the substrate for supporting the electro-optic element (27), as shown in Figure 4d, gives a display which has less parallax than the

display (10e) which incorporates glass substrate (32). This is because diffusing layer (28) is typically less than 100 micrometers thick.

Referring to Figure 4c, the operation of display (10c) will now be described. In bright ambient light, light passes through the display as indicated by arrow a. Light is scattered by diffusing layer (28), passes through the transparent organic material layer (20), and is reflected at the aluminium layer (22). As layers (20) are optically transparent, colourless, and optically isotropic, the performance of display (10c) when operating in reflective mode is comparable to a conventional purely reflective LCD. Additionally, the brightness of the display (10c) is substantially greater than that of a transflective LCD, and the diffusing layer (28) increases the viewing angle of the display.

In low ambient lighting conditions, a voltage of, for example, approximately 3 to 15 V is applied between the aluminium cathode (22) and the ITO anode (18). This causes current to flow in the organic material layer (20), which in turn leads to the emission of light from the light emitting layer (20b). Again, the performance of the display will be greater than that achieved with a conventional transflective display. This is because, for a transflective display, only 40% of the light from the backlight is transmitted by the transflector.

A liquid crystal display incorporating the invention provides good image quality in all ambient lighting conditions.

Another advantage of the invention is that the electro-optic element (when formed on a polarising layer) is very thin, typically less than 1 micrometer.

The invention has been described by a number of embodiments, and it will be appreciated that variation may be made to the embodiments without departing from the scope of the invention. For example, an electro-optic element may be provided without hole transporting layer (20a) and/or electron transporting layer (20c).

Claims

transporting material are substantially optically isotropic so that the polarisation of the light passing therethrough is not substantially altered.

9. A liquid crystal display (10a,b,c,d) according to any of claims 3 to 8 wherein the layer (20b) of light emitting material is substantially colourless so that the colour of the light passing therethrough are not substantially altered.

10. A liquid crystal display (10a,b,c,d) according to any of claims 5 to 9 wherein the layer (20a) of hole transporting material and/or the layer (20c) of electron transporting material are substantially colourless so that the colour of the light passing therethrough are not substantially altered.

11. A liquid crystal display (10a,b,c,d) according to any of claims 5 to 10 wherein the second electrode (22) is disposed adjacent the layer (20a) of electron transporting material.

12. A liquid crystal display (10a,b,c,d) according to any of claims 3 to 11 wherein the second electrode (22) includes aluminium, magnesium, silver and/or calcium.

13. A liquid crystal display (10a,b,c,d) according to any of claims 3 to 12 wherein the first electrode (18) includes Indium Tin Oxide (ITO) and/or Tin Oxide.

14. A liquid crystal display (10a,b,c,d) according to any of claims 5 to 13 wherein the first electrode (18) is disposed adjacent the layer (20a) of hole transporting material.

15. A liquid crystal display (10a,b,c,d) according to any of claims 3 to 14 wherein the light emitting material includes an organolanthanide.

16. A liquid crystal display (10a,b,c,d) according to any of claims 5 to 15 wherein the hole transporting material includes an aromatic diamine.

17. A liquid crystal display (10a,b,c,d) according to any of claims 5 to 16 wherein the electron transporting material includes a derivative of triazole.

Claims

1. A liquid crystal display (10a,b,c,d) capable of operating in a first mode and a second mode, the display comprising: a liquid crystal device (14), and an electro-optic element (27), characterised in that in the first mode the electro-optic element functions as a backlight and in the second mode the electro-optic element functions as a reflector, and the display (10a,b,c,d,e) includes a diffusing means (28) in order to increase the viewing angle of the display.

2. A liquid crystal display (10a,b,c,d) according to claim 1 wherein the first and second modes are the transmissive mode and the reflective mode, respectively.

3. A liquid crystal display (10a,b,c,d) according to claim 2 wherein the electro-optic element (27) comprises a substantially optically transparent first electrode (18), a second electrode (22), and a layer (20b) of substantially optically transparent light emitting material disposed therebetween.

4. A liquid crystal display (10a,b,c,d) according to claim 3 wherein the second electrode (22) is reflective.

5. A liquid crystal display (10a,b,c,d) according to claim 3 wherein the electro-optic element (27) further includes a layer (20a) of hole transporting material and/or a layer (20c) of electron transporting material, the layer (20b) of light emitting material disposed therebetween.

6. A liquid crystal display (10a,b,c,d) according to claim 5 wherein the layer (20a) of hole transporting material and/or the layer (20c) of electron transporting material are substantially optically transparent.

7. A liquid crystal display (10a,b,c,d) according to any of claims 3 to 6 wherein the layer (20b) of light emitting material is substantially optically isotropic so that the polarisation of the light passing through it is not substantially altered.

8. A liquid crystal display (10a,b,c,d) according to any of claims 5 to 7 wherein the layer (20a) of hole transporting material and/or the layer (20c) of electron

18. A liquid crystal display (10a,b,c,d) according to any of claims 3 to 17 wherein the electro-optic element (27) includes a means of applying a voltage to the first electrode (18) and the second electrode (22).

19. A liquid crystal display (10a,b,c,d) according to any preceding claim including a first polarizing means (12).

20. A liquid crystal display (10a,b,c,d) according to any preceding claim including a further polarizing means (16).

21. A liquid crystal display (10a,b) according to claim 19 or claim 20 wherein the diffusing means (28) is disposed adjacent the first polarizing means (12).

22. A liquid crystal display (10b) according to any of claims 19 to 21 wherein the diffusing means (28) is disposed between the first polarizing means (12) and the liquid crystal device (14).

23. A liquid crystal display (10c) according to any of claims claim 20 to 22 wherein the diffusing means (28) is disposed between the liquid crystal device (14) and the further polarizing means (16).

24. A liquid crystal display (10d) according to any of claims 16 to 23 wherein the diffusing means (28) is disposed between the further polarizing means (16) and the electro-optic element (27).

25. A liquid crystal display (10a,b,c,d) according to any of claims 3 to 20 wherein the second electrode is formed such that it diffuses light.

26. A liquid crystal display (10a,b,c,d) according to any preceding claim wherein the liquid crystal device (14) includes liquid crystal material.

27. A liquid crystal display (10a,b,c,d) according to claim 26 wherein the liquid crystal material is optically scattering in at least one state such that it diffuses light.

28. A liquid crystal display (10a,b,c,d,e) according to any preceding claim further including a layer (32) of transparent material.

29. A liquid crystal display (10a,b,c,d,e) according to any preceding claim further including an encapsulating layer (24).

30. A liquid crystal display (10a,b,c,d,e) according to claim 29 wherein the encapsulating layer (24) is disposed adjacent the second electrode (22).

31. A liquid crystal display (10a,b,c,d,e) according to claim 29 or claim 30 wherein the electro-optic element (27) is disposed between the further polarizing means (16) and the encapsulating layer (24).

32. A liquid crystal display (10a,b,c,d,e) according to any of claims 29 to 31 wherein the electro-optic element (27) is disposed between the diffusing means (28) and the encapsulating layer (24).

33. A liquid crystal display (10e) according to any of claims 29 to 32 wherein the electro-optic element (27) is disposed between the further layer (32) of transparent material and the encapsulating layer (24).

Fig.1.

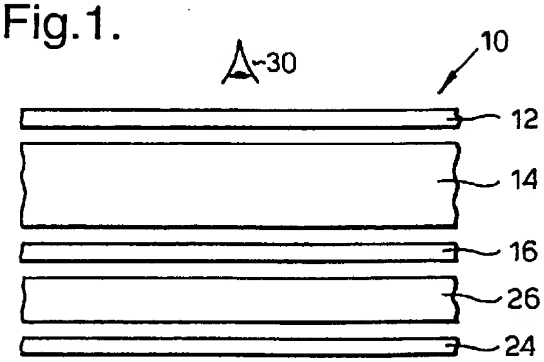


Fig.2.

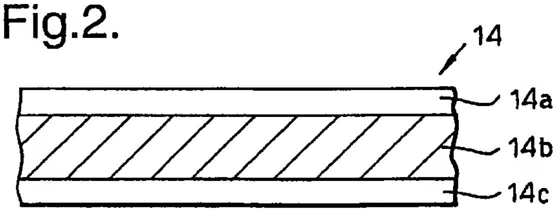


Fig.3.

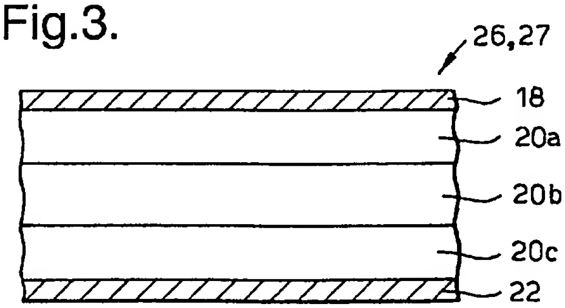


Fig.4a.

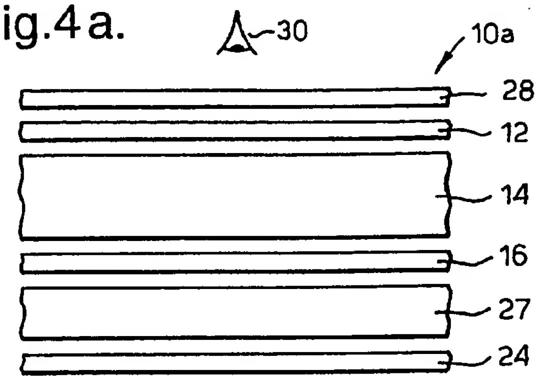


Fig.4b.

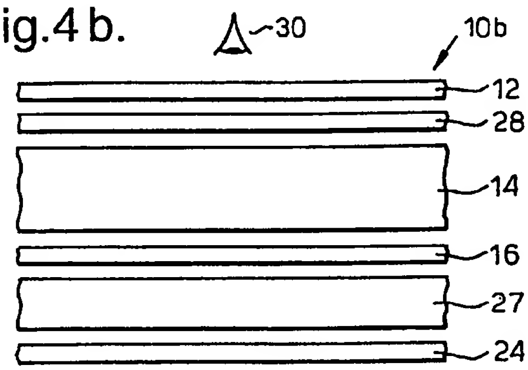


Fig.4c.

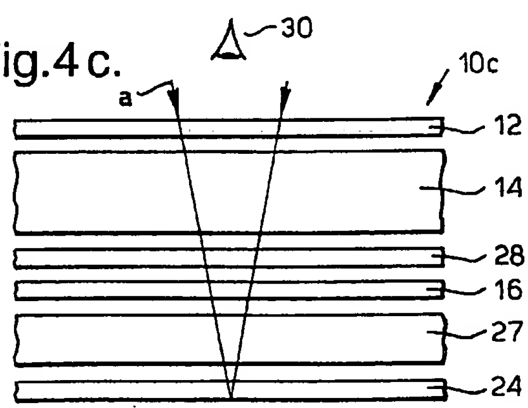


Fig.4d.

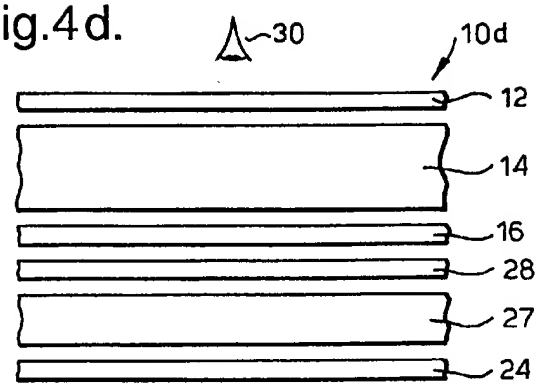
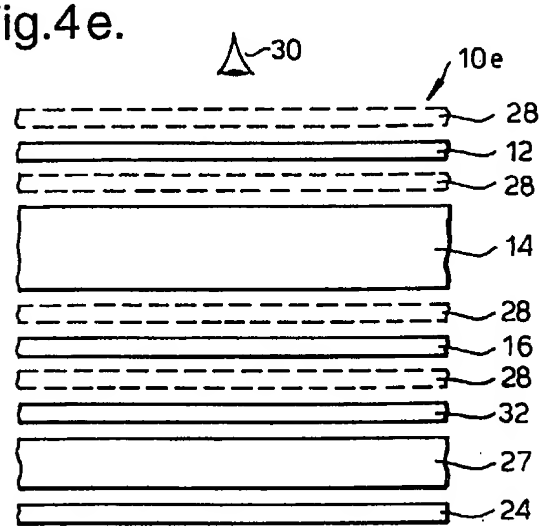


Fig.4e.



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/00497

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02F1/13357

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02F G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 08, 30 June 1998 (1998-06-30) & JP 10 078582 A (CASIO COMPUT CO LTD), 24 March 1998 (1998-03-24) abstract & US 6 025 894 A 15 February 2000 (2000-02-15) column 12, line 62 -column 14, line 3 column 18, line 10 - line 52; figures 1,2,10,11 family member 'P! ---	1-6, 9-14, 16-26,28
X	US 5 686 979 A (AASTUEN DAVID J W ET AL) 11 November 1997 (1997-11-11) column 11, line 42 -column 13, line 50; figures 9-11 --- -/--	1,2

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 June 2000	05/07/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Manntz, W

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/00497

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 5 986 730 A (GUNTHER JOHN E ET AL) 16 November 1999 (1999-11-16) the whole document	1,2
A	US 5 841 494 A (HALL DENNIS R) 24 November 1998 (1998-11-24) column 5, line 13 -column 6, line 50; figures 4,5	1-4

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte onal Application No
PCT/GB 00/00497

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
JP 10078582	A	24-03-1998	US	6025894 A	15-02-2000
US 5686979	A	11-11-1997	AU	5964696 A	30-01-1997
			BR	9608641 A	29-06-1999
			CA	2224324 A	16-01-1997
			EP	0835475 A	15-04-1998
			JP	11508377 T	21-07-1999
			WO	9701789 A	16-01-1997
US 5986730	A	16-11-1999	WO	0033132 A	08-06-2000
US 5841494	A	24-11-1998	NONE		